

Effective Contamination Control For Gearboxes

Understanding the different contaminant types and where they come from will help operators to design an effective program.

BY JUSTIN STOVER

The lubrication of wind turbines has come a long way since the early days of the American West. Pioneers and farmers would climb up a windmill tower with a grease bucket in hand. Balanced high atop the tower on a platform, the grease would be applied perilously to the open gears.

As modern wind turbine gearbox design has evolved, so has the lubrication of these systems. Today more than ever, an increasing demand is put upon lubricants in terms of operating temperatures, loads and performance. The oil film in rolling element bearings which separates gear teeth is only a few microns thick, making it invisible to the naked eye.

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Therefore, it is essential to control contamination effectively. It is well established that cleaner oil leads to longer life of bearings and gears.

This article addresses basic contamination control measures that will help end users to maximize the performance of lubricants, achieve greater reliability, and improve the lifetime of gear oil and the equipment itself. These recommendations are made under the assumption that the correct lubricant is selected, gearbox loads are understood, and the proper design and specification of gearbox components have been applied.

Contamination control

Contamination control is defined as the planning, organizing, managing and implementing of all activities required to determine, achieve and maintain a specified contamination level. You may already be familiar with this concept in your daily life. Most of us strive to maintain a healthy lifestyle. What happens, though, if a person begins to fall behind in these activities? When the weight goes up, hopefully we take corrective actions. Similarly, contamination control involves setting reachable goals and taking proper steps to reach them. When these goals are not met, correc-

tive action is taken.

For the wind turbine owner and operator, lower contamination levels will mean a longer lifetime – not only for the lubricant, but also the components it serves and protects. Research conducted over 25 years ago at London's Imperial College by Sayles and Macpherson demonstrated that rolling element bearing life in gearboxes was extended by nearly six times when a 3-micron filter was used instead of a 40-micron filter.

Therefore, contamination can control you through increased friction and wear, failures and unplanned stoppages. However, the good news is that you can control contamination to such an extent that these problems are minimized. Since contamination control involves planning, organizing and managing, an understanding of contaminants is needed to effectively control them. Let's consider what types of contaminants there are and where they come from.

Contaminant types

By definition, contaminants are anything in the oil that should not be present. There are three basic types of contaminants that threaten wind turbine gearboxes:

- Solid particle contaminants.

These include dirt, silicon, iron, copper and lead, among others. Solid particles act as an abrasive, similar to sandpaper. These particles are typically much harder than materials used in gearbox components and become harder due to the process of work-hardening.

The sources could be built in during manufacturing and assembly. They also could be internally generated as a result of various wear modes or by ingress through vents and breathers, ineffective or damaged seals, new oil, and during maintenance activities.

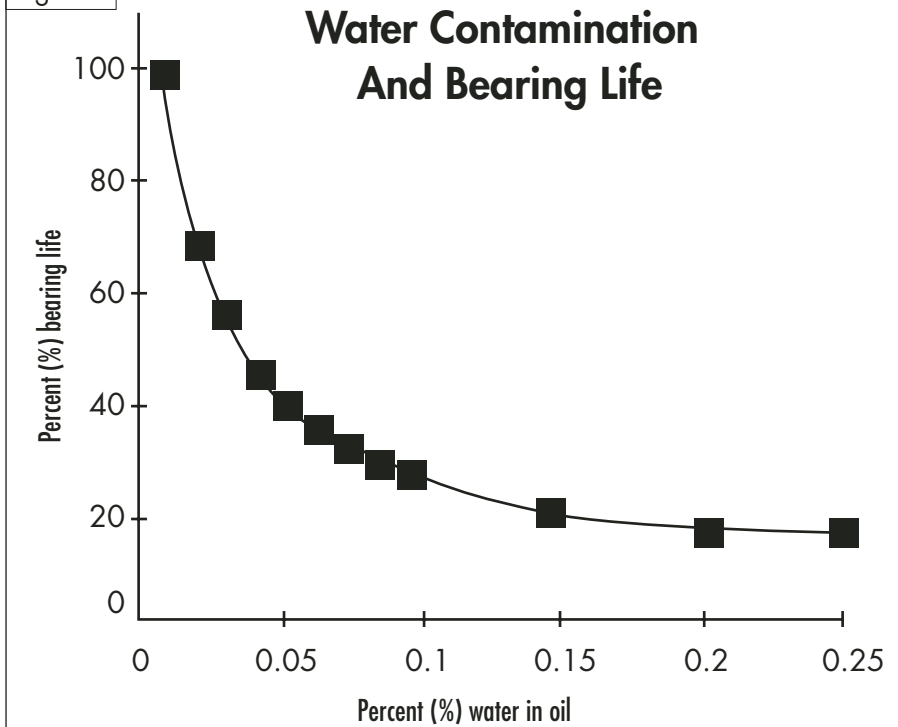
- Moisture contamination. Water can have a devastating effect on the gearbox and lubricant life (Figure 1). Like the air surrounding us, gear oil will dissolve a small amount of moisture. When water exceeds the saturation point, typically greater than 500 ppm, emulsified and free water will be present and cause damage. Excessive moisture interferes with lubrication by weakening the oil film strength, depleting additives and promoting oxidation.

Like particles, water can be ingressed through vents and breathers, condensation, new oil and during maintenance activities.

- Soft particle contaminants. Oxidation is influenced by heat, moisture and contaminants that act as catalysts (copper, for example). The oxidation rate doubles every 10 degrees C (18 degrees F) above 60 degrees C (140 degrees F). Likewise, air in the lubricant increases oxidation. Entrained air is caused by excessive agitation in the gearbox, low oil volume, moisture contamination or depleted foam additive.

Byproducts of oxidation will produce insoluble and soluble contaminants such as sludge and varnish. These byproducts contain oxygen, which makes them polar. Their polar nature makes it easier for them to adsorb to metal surfaces and other polar compounds. Further oxidation turns these byproducts into carboxylic acids. These acids are aggressive and will attack component sur-

Figure 1



Source: CC Jensen Inc.

faces and leave deposits throughout the gearbox.

Oxidation of lubricants can occur as a result of high temperatures, moisture contamination and excessive particle contamination. Cross contamination from old oil when new oil is added to the gearbox is also possible.

With a basic understanding of contaminant types and their source, it now becomes possible to set up an effective contamination control program. Following are three steps to implementing such a program.

Set oil cleanliness targets

This is perhaps the easiest step because much of the work has already been done for the wind energy industry. The American Wind Energy Association (AWEA) and the American Gear Manufacturers Association (AGMA) have released a technical standard that sets forth reasonable and attainable targets. Committee members took an engineering approach in setting lubricant cleanliness guidelines.

The standard is titled "ANSI/AGMA/AWEA 6006-A01: Design and Specification of Gearboxes for Wind Turbines." The targets are found in

section six, Lubrication.

The ISO Code refers to a logarithmic scale used in determining the cleanliness of lubricating fluids. It is known as ISO 4406:1999. The number of particles in 1 mL of fluid are counted and arranged according to size. The three-code system assigns a number to particles equal to or greater than 4 micron, 6 micron and 14 micron. This allows for a simple yet effective means to quantify and monitor fluid cleanliness.

The AGMA/AWEA standard also includes guidelines for moisture contamination in Annex F. The caution level is 0.05% (500 ppm) and the critical level is 0.10% (1,000 ppm). So an effective contamination control program should aim for 0.05% or lower.

This standard serves as a guideline only and should be viewed as a ceiling level. The ISO Code target should also take into consideration the severity and cost of failures as well as the reliability goals of the organization. Therefore, setting a lower ISO Code and moisture targets will translate into greater reliability and life extension.

Most contamination control programs only address water and hard

particles. Bring your program to the next level by addressing the third main contaminant type: soft particles. Unlike water and hard particles, there is not a convenient international standard or quantitative assessment for soft particles.

Nevertheless, the cleanliness target should involve keeping soft particles to a minimum. Generally speaking, if solid particles and moisture contamination, along with high temperatures, are controlled, oxidation will be kept to a minimum. Therefore, as the expression goes, keep the oil “cool, clean and dry.” This leads us to the second step, which involves the implementation of activities to achieve the goals set forth above.

Take action to reach targets

Achieving any type of goal requires that we take action. In this context it requires that two specific actions be taken.

First, reduce contaminant ingestion. In other words, keep particles from getting into the gearbox. Follow good housekeeping procedures in the storage, handling and dispensing of lubricants. Ensure that lubricants are kept clean and dry. Avoid cross contamination by clearly labeling containers as to the oil type. Use filter carts to clean and dispense oil from drums. Portable containers can be directly filled from the filter cart, ensuring clean oil is added to the gearbox.

During maintenance events, take great care to minimize the entry of contaminants into the gearbox. Add oil from a portable filter system with quick disconnect fittings.

Breathers should have a filter and desiccant to remove ambient dirt, dust and moisture. Use labyrinth seals and V-rings.

Second, improve filtration. Remove particles and water quickly. A well-designed filtration system will effectively remove not only solid particles, but also moisture and soft contaminants.

Most large wind turbines have an inline filter located in the cooling sys-

tem. However, these filters must, out of necessity, have a larger pore size than the oil film thickness, typically 10 micron or larger. Because the oil flow rates required by the cooler are high, a finer filter is not an option, as this would make the inline filter fairly large. As a consequence, these filters have a low dirt-holding capacity, and in some cases require frequent changes.

The solution is to supplement the inline filter with an offline filter. Offline filters are installed independent of the gearbox. Here a finer filter can be used, typically around 3 micron, because the oil flow requirements are less than 1 gallon per minute. Offline filters are depth type filters, meaning that they have a larger surface area than inline filters. Therefore, they have a higher dirt holding capacity providing a longer service life.

Oil sampling procedures should be carried out by trained personnel to ensure representative samples.

Furthermore, the offline filter can run continuously, even during shutdown. Cellulose-based offline filters have the further capability of removing moisture by absorption and soft contaminants by means of a strong polar attraction.

A well-designed contamination control system incorporating inline and offline filters will reach oil cleanliness targets and provide operational economy. A common myth is that increased filtration costs outweigh the benefits of achieving cleaner oil. Savings usually outweigh costs by great margins because of longer filter service life, lower oil consumption, and extended gearbox and bearing lifetime.

Monitor oil cleanliness

The final element of an effective contamination control program is to regularly monitor the oil's condition and take appropriate action when goals are not met. Oil monitoring can be accomplished in the field or by an experienced laboratory.

Monitoring indicates how well the filter system is performing and also alerts the user to potential failures. A typical test slate will include the ISO Code, water content, acid number, elemental analysis and viscosity.

Oil sampling procedures should be carried out by trained personnel to ensure representative samples. Samples should be drawn from live zones and preferably during operation. As mentioned earlier, an offline filter with an integrated sample valve provides adequate circulation for sampling, even when the turbine is shut down. Sampling frequency should be carried out every six to 12 months. The future of condition monitoring will include the use of online sensors to provide real-time data.

In summary, the three steps to an effective contamination control program are:

- Define targets for particle and water contamination and oil properties;
- Instigate remedial action as necessary to reach targets; and
- Monitor contamination levels against target levels and maintain safe levels.

Benefits of contamination control

A wind turbine operator in North America kicked off a contamination control program by establishing oil cleanliness goals according to the ANSI/AGMA/AWEA guidelines.

Applying step three first, the operator found that his oil cleanliness was over the target at 18/17/13. The decision was made to improve filtration by adding an offline filter to the system. The result after 24 hours was a lowering of the ISO Code to 15/14/10.

The benefits of improving oil cleanliness, as demonstrated above, will mean the following:

- increased gearbox and bearing lifetime;
 - longer oil service life;
 - reduced lubricant consumption;
- and
- decreased environmental impact.

Conclusions

Contamination control is an essential part of an effective wind turbine maintenance program. It provides what is perhaps the single greatest opportunity for gains in

terms of reliability and life extension. Significant savings are achieved through longer oil and component lifetime. The relationship between lubrication quality and maintenance costs is inversely proportional. Financial gains are made when the gear oil quality and cleanliness level are improved.

Understanding the three different contaminant types and where they come from will help owners and operators to design an effective program.

Such a program sets cleanliness targets, takes specific steps to restrict the ingestion of contaminants, and removes them efficiently by upgrading filters to prevent the accumulation of particles, wear and oxidation byproducts.

Finally, the program is brought into balance by monitoring the progress and taking appropriate action to again reach the target cleanliness.

Given the damage contamination can bring to a wind turbine, controlling it is well worth the effort. **NP**